Volcanic Health Effects & Risk Assessment

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Volcanic Air Pollution (VAP)

Gases:
- Water vapor $H_2O$
- Sulfur dioxide $SO_2$
- Carbon dioxide $CO_2$
- Hydrogen sulfide $H_2S$
- Hydrogen chloride $HCl$
- Hydrogen fluoride $HF$
- Radon

Fine Particles:
- Sulfuric acid aerosol
- Sulfates

$H_2S \rightarrow SO_2 \rightarrow H_2SO_3 \rightarrow [NH_4]_2SO_4$

Terrestrial (≤0.3 μm size)

Oceanic (≤1.7 μm size)

PM + gas/aerosol

Natural & anthropogenic


Defense Mechanisms of the Respiratory System

1. Nasal filtration of particles/gases
2. Pharynx
3. Lymphatic vessels
4. Exudation of mucus

Fine particles - $PM_{10}, PM_{2.5}$ are respirable

Table: Description of Gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Description</th>
<th>Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SO_2$</td>
<td>Colorless, Odorless, $0.05%$ of air</td>
<td>Respiratory &amp; dermal irritation, bronchoconstriction &amp; inflammation, exacerbation asthma/COPD</td>
</tr>
<tr>
<td>$H_2S$</td>
<td>Colorless, Odorless, $0.02%$ of air</td>
<td>Asphyxiant, URT irritation, bronchitis, asthma, death from acute respiratory distress syndrome - pulmonary edema - cardiac arrhythmias</td>
</tr>
<tr>
<td>$CO_2$</td>
<td>Colorless, Odorless, $0.03%$ of air</td>
<td>Asphyxiant, respiratory drive, causes CNS excitation followed by CNS depression</td>
</tr>
<tr>
<td>$HCl$</td>
<td>Colorless, Odorless, $0.01%$ of air</td>
<td>Respiratory &amp; dermal irritation, bronchoconstriction &amp; inflammation, RADS - pulmonary edema</td>
</tr>
</tbody>
</table>

AEGL = Acute Exposure Guideline Levels – 1 – non-disabling
IDLH = Immediate Danger to Life or Health

References: ATSDR, WHO, NRC - Acute Exposure Guideline Levels for Selected Airborne Chemicals
### Compound Description

<table>
<thead>
<tr>
<th>Compound</th>
<th>Description</th>
<th>Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄ aerosol</td>
<td>Colorless</td>
<td>Respiratory &amp; dermal irritant; pulmonary functioning; mucociliary transport, alveolar clearance &amp; phagocytosis; exacerbation asthma/COPD</td>
</tr>
<tr>
<td>PM sulfate, ash</td>
<td>Colorful Haze</td>
<td>Restrictive pulmonary diseases (COPD); decrease pulmonary functioning, chronic bronchitis, pneumonia, exacerbation asthma/COPD, alveolar damage, cardiovascular effects, ocular effects</td>
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### Environmental Exposure

1. What is the air pollution from the volcano?
2. How much? *Amounts, compared to...*
3. What populations are at risk? *Locations*

### Environmental Exposure Assessment for Public Health

- Regional assessment vs. point source testing
- Remote sensing (NASA ARSET)
- Measurements
  - Ambient & indoor
  - Cross sectional vs. continuous
  - Long-term average
  - Real-time

### Different pollutants in different locations

- Regional Survey in 2003
- Hot Spots

Published in Geology, 2005
Cost, Time, Geographic Coverage

SO$_2$ pulse fluorescence monitor

Accuracy +5%

24-hour patterns of SO$_2$ and PM$_{1.0}$ concentration averages during Trade Winds

Pahala Air Quality Monitor, data from State of Hawai‘i

SO$_2$ Penetration Indoors

<table>
<thead>
<tr>
<th>Indoor Penetration</th>
<th>Locations</th>
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</thead>
<tbody>
<tr>
<td>69%</td>
<td>School Cafeteria</td>
</tr>
<tr>
<td>59% - 85%</td>
<td>School Classrooms</td>
</tr>
<tr>
<td>56% - 68%</td>
<td>Plantation Houses</td>
</tr>
<tr>
<td>15% - 23%</td>
<td>Modern Houses</td>
</tr>
<tr>
<td>71% - 91%</td>
<td>Hospital Dayroom</td>
</tr>
<tr>
<td>65%</td>
<td>Hospital Clinic</td>
</tr>
<tr>
<td>85%</td>
<td>Emergency Department</td>
</tr>
</tbody>
</table>

Published: Geology, 2005; Family & Community Health, 2010

Volcanic Activity Changes

Summit 2008 - present

Pu‘u O‘o 1983-92 Puna caldera

Napau Crater 2011 Puna caldera

Kamoamoa Eruption Air Quality March 6-9th 2011 Average Concentrations over 24-hours

Pahala Town 30km

Ocean View 60km

Captain Cook 90km

Published: Geology, 2005; Family & Community Health, 2010
How much \( \text{SO}_2 \) is too much?

Before June 2010:
- \( \text{SO}_2 \) 24-hour Average (Standard = 140 ppbv)

After June 2010:
- \( \text{SO}_2 \) 1-hour Average (Standard = 75 ppbv)

\( \text{ATSDR} \) – MBL \( \text{SO}_2 = 10 \) ppbv for exposure <14 days

Remember the sensitive populations

EPA – Before June 2010
- \( \text{SO}_2 \) 24-hour Average
  - Standard = 140 ppbv

EPA – NOW
- \( \text{SO}_2 \) 1-hour Average
  - Standard = 75 ppbv

World Health Organization’s
- 24 hr \( \text{SO}_2 \) guideline is 8 ppbv

How much \( \text{SO}_2 \) is too much?

Health Effects
1. How many residents are having effects?
2. How much of a change in morbidity is occurring?
3. What is the impact on health care services?
4. Any long-term effects in population health?

Methods for Epidemiologic Assessment
- Cohorts (based on exposure status)
  - Comparison
- Baseline
  - Existing data sets
  - Prevalence Survey
- Prospective
  - Adult & birth cohorts
  - Sensitive members
- Retrospective

What to collect?
- Resident Self – reported health information
- Health survey by clinicians
  - The Volcano Health Questionnaire
- Medical records
  - EDs
  - Health systems
- Acute signs & symptoms (prevalence)
- Medical Diagnoses (incidence)

Poor Air Quality
EPA & State of Hawai’i
Exceedances for sulfur dioxide gas

Year 2011 = 46% of days exceeded

This year 2012 (January – April):
- 93% of the days exceeded
- Only 8 clean air days

Urban + VAP = Higher Impact

Consider location of cities with urban pollution problems to volcanic areas

Worst USA Cities List:
- #1: Bakersfield-Delano, CA
- #2: Hanford-Corcoran, CA
- #3: Los Angeles-Long Beach-Riverside, CA
- #4: Visalia-Porterville, CA
- #5: Fresno-Madera, CA
Concerns from Hawaii's clinicians
- National Park workers have symptoms (NIOSH – Stephenson et al., 1991)
- Significant findings for ED respiratory illness (CDC – Mannino et al., 1996; U of H – Michaud et al., 2004; State of Hawaii, 2009)
- No evidence to date for cause of asthma (U of H – HCILASS Study ongoing)
- Increased self-reported symptoms in exposed population
  - Daily cough, eye irritation, runny nose, sore throat, wheezing, headaches, high blood pressure
  - (Published in Public Health, 2008; Nursing Research 2009)

Human Health
- Higher risk of acute medical illnesses:
  - Asthma attacks, bronchitis, pharyngitis, URI, cough
  - Children (<15 years old) most affected (Published in Journal of Toxicology & Environmental Health, 2008, 2010)
- Quality of life affected in persons with chronic respiratory disease
- Smokers report the most problems (Published in Nursing Research, 2009)

Acute Bronchitis
- 57% higher risk
- Standardized cumulative incidence rates
  - Exposed cohort: 185.7 per 1,000
  - Unexposed cohort: 117.2 per 1,000
  - Relative Risk: + 57% (95% CI = 1.36-1.81)
  - Highest risk in exposed children (0-14 yrs)
  - RR = 6.46 (3.16-13.60)
- Exposed cohort current smoking (19%), unexposed cohort (27%)

Disease BURDEN:
- 68 more visits in exposed area per 1,000 residents

Acute Pharyngitis
- "double the risk"
- Standardized cumulative incidence rates
  - Exposed cohort: 234.2 per 1,000
  - Unexposed cohort: 102.4 per 1,000
  - Relative Risk: + 229% (95% CI = 1.85 - 2.84)
  - Highest risk in exposed children (0-14 yrs)
  - RR = 2.86 (1.72 - 4.74)

Disease BURDEN: 136 more visits in exposed area per 1,000 residents

Acute upper respiratory infections
- 12% higher risk
- Standardized cumulative incidence rates
  - Exposed cohort: 498.9 per 1,000
  - Unexposed cohort: 447.3 per 1,000
  - Relative Risk: + 12% (95% CI = 1.02 - 1.22)
  - Highest risk in exposed children (0-14 yrs)
  - RR = 2.29 (1.76 - 2.95)

Disease BURDEN: 99 more visits for exposed children per 1,000 residents
Relative Risk Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>Disease Burden</th>
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<tr>
<td>2004-2007</td>
<td>3.19 (2.34 - 4.33) per 1,000 residents/yr</td>
</tr>
<tr>
<td>2008-April 2009</td>
<td>8.71 (6.48 - 11.93) per 1,000 residents/yr</td>
</tr>
</tbody>
</table>

Total Population:
- 2004-2007: 1.87 (1.50 - 2.33) per 1,000 residents/yr
- 2008-April 2009: 3.19 (2.34 - 4.33) per 1,000 residents/yr

Children (0-14 years):
- 2004-2007: 5.10 (2.69 - 9.66) per 1,000 children/yr
- 2008-April 2009: 8.72 (3.98 - 19.13) per 1,000 children/yr

- 4x more cases with higher VAP

Primary Prevention

**GOAL**: Minimize Exposure to VAP
- **Encourage**:
  - Self Care on Heavy VAP Days: no exercise, stay indoors, AC
  - Supplies in car/home (emergency & ash - protection)
- **Educate**:
  - Residents on the “Clean Air” hours during usual wind conditions
  - All residents to use the “real time” air quality measurements from the Air Quality division on the Internet
  - Emergency Response Plan

Secondary Prevention

**GOAL**: Identify early & treat properly
- **Screen**:
  - Heart & Lung disease
  - Community health fairs
  - Include spirometry in annual physicals
- **Educate**:
  - Illness Symptoms in children
- **Treat**: Smoking - nicotine dependency

Primary Prevention

**GOAL**: Minimize Exposure to VAP
- **Complete as needed**:
  - Disaster Shelter(s) & Hospital renovations
- **Develop**:
  - School’s VAP Response Plan (equipment, training)
  - Hospital’s VAP Response Plan (air quality; influx of patients)
  - Assistance to Senior Centers & Homebound persons
  - Volcanic Emergency Response Plan (evac, refresh, equipment)
  - Communication with USGS volcanologists

Secondary Prevention

**GOAL**: Identify early & treat properly
- **Screen**:
  - Heart & Lung disease
  - Community health fairs
  - Include spirometry in annual physicals
- **Educate**:
  - Illness Symptoms in children
- **Treat**: Smoking - nicotine dependency

Compared to adults:
- Children: more physically active
- Breathe faster
- Mouth breathe more
- Air passes over lungs = Higher VAP dose

What can we do to prevent disease?

PUBLIC HEALTH FRAMEWORK

**Primary Prevention**:
- Prevent onset
- Promote general health

**Secondary Prevention**:
- Detect early & treat promptly

**Tertiary Prevention**: Chronic Disease
- Prevent progression of disease
- Maintain Quality of life

Does everyone know what to do?
GOAL: Reduce Disease Progression

Persons with Asthma:
- Ensure patients have a current “Asthma Action Plan”
  - Use Guidelines from the National Heart Lung and Blood Institute
  - Provide the area’s clinicians with educational program from the Institute
- Follow the California Department of Public Health’s:
  - “Guidelines for the Management of Asthma in California Schools”
  - “Asthma Action Plan for Schools and Families”

GOAL: Reduce Disease Progression

Persons with heart disease:
- Promote self care:
  - Importance of taking their heart & BP medicine
  - Communicating with their doctor or nurse practitioner
  - Monitoring their BP
  - Eating “Heart Healthy”

50% of residents at Kilauea were not taking their BP medicine